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(54) Title: SPURIOUS RESPONSE REJECTING MIXER USING SPREAD SPECTRUM TECHNIQUES

(57) Abstract

A mixing circuit uses spread spectrum techniques to discriminate between desired signals and image responses associated with frequency translation, signal mixing and the like. In a receiver, the radio frequency (R.F.) signal is mixed with a first spread spectrum local oscillator (L.O.) producing a spread spectrum intermediate frequency (I.F.) signal. The spread spectrum (I.F.) is filtered and mixed with a second spread spectrum (L.O.) which de-spreads the desired signal in the (I.F.). The second (L.O.) is driven with the same spreading function as the first (L.O.) therefore the desired signal is correctly de-spread while the spurious signals are not. The circuit is equally useful in both receivers and transmitters. In general, the circuit is useful in any system where two or more signals are multiplied and it is desired to reject spurious signals.

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SPURIOUS RESPONSE REJECTING MIXER USING SPREAD SPECTRUM TECHNIQUES

BACKGROUND OF INVENTION

This invention relates generally to communications systems and more specifically to mixing and filtering circuits for communications systems.

Numerous types of communication systems are well known including radio, television, telephone, microwave, satellite, fiber optic communications, and others. The operation of most communications systems is similar in that each system mixes a base signal with a carrier frequency to produce a modulated signal which is transmitted through some medium(e.g. air, cable, optical fiber, etc.) A receiver then reverses this process and recovers the original base signal.

Figure 1 illustrates a simplified communications system. In a transmitter 10, a base signal is mixed with a carrier frequency in mixer 11 producing a modulated signal. The modulated signal is radiated by transmitting antenna 12 to receiving antenna 13. In receiver 14, mixer 15 mixes the received signal with a local oscillator to recover the original base signal. Filters 16A, 16B, 16C, and 16D block undesired noise at each step of the process and provide a clearer signal.

A common problem in communication systems is separating the desired signal from noise, spurious signals, and the like. One type of noise, known as spurious responses, are generated as a result of mixing two signals as described above. Mixing two signals generates responses at the sum and difference frequencies of the mixed signals and multiples thereof. This is shown in the formula:

$$f_s = (M * f_1) +/- (N * f_2)$$

where f_s represents the response frequencies generated, f_1 and f_2 are the signals mixed, and M and N are integers.

The problem is easily demonstrated by example. Suppose it is desired to translate an 80 MHz signal down to 10 MHz in a receiver. A 90 MHz local oscillator(L.O.) can be used since 90 - 80 = 10. However, an undesired signal at 100 MHz is also translated to 10 MHz since 100 - 90 = 10. In this example the undesired signal (or image response) is translated to the same frequency as the desired signal and once both signals are mapped to the same frequency it is difficult if not impossible to separate them.

The prior art attempts to solve this problem by filtering the signals before and after mixing as shown in Figure 1. Filters 16A, 16B, 16C, and 16D in Figure 1 are designed to pass the desired signal while blocking undesired signals. In actual communications systems, complex circuits having multiple mixers, pre-filters, post-filters, signal amplifiers, and complex digital signal processing techniques are used to separate desired signals from noise and spurious responses.

The prior art techniques are a disadvantage, however, when the desired signal covers a wide frequency range. Also, spurious inputs sometimes fall very close to or overlap the desired signal frequency range making it difficult to construct a filter with the desired rejection characteristics. The problem is accentuated when working with weak signals such as those used in satellite communications or when the circuit must operate near other circuits which also have multiple mixers which generate spurious signals.

Clearly there exits a need for an improved circuit and method for mixing signals which effectively discriminates between desired signals and image responses, requires fewer filters, and is simple in design.

SUMMARY OF THE INVENTION

The invention creates a mixing circuit which uses spread spectrum techniques to discriminate between desired signals and image responses associated with signal mixing, frequency translation, and the like. In a receiver, the radio frequency(R.F.) input signal is mixed with a spread spectrum local oscillator(L.O.) producing a spread spectrum intermediate frequency(I.F.) signal. The spread spectrum I.F. signal is then filtered and mixed with a second spread spectrum L.O. which de-spreads the I.F. signal. The second L.O. is driven with the same spreading function as the first L.O. and therefore the desired signal is correctly de-spread while the spurious signals, including images, are not. The circuit is equally useful in both transmitters and receivers. In general, the circuit is useful in any system where two or more signals are multiplied and it is desired to reject spurious signals.

Spread spectrum communications are well known in the art. Spread spectrum is a means of communicating by purposely spreading the spectrum of a communications signal well beyond the bandwidth of the unspread signal. A receiver de-spreads the communications signal back to its original bandwidth to recover the desired signal.

Spread spectrum communication is particularly useful in military applications since, 1) the power of the transmitted wave is "spread" over a large bandwidth and is easily disguised as noise, and 2) the signal can not be easily "de-spread" without knowing the spreading code or function.

Spread spectrum communication systems function essentially the same as the conventional communications system, however, in spread spectrum systems the carrier frequency in the transmitter and the L.O. in the receiver are both spread spectrum signals. Discussion of spread spectrum techniques are available in many publications including the Encyclopedia Of Electronics And Computers, 2nd ed., published in 1988 by McGraw-Hill, pgs. 847-849, which is incorporated herein by reference.

It has been discovered that spread spectrum techniques can be used in a new way to reject image responses and spurious signals when mixing two or more signals. The invention uses two mixers and two spread spectrum signals to first spread an input signal and then de-spread only the desired signal while leaving the undesired signals spread. A first mixer mixes the input signal with a first spread spectrum signal thus producing a spread spectrum I.F signal. The mixer is any signal mixer commonly known in the art. Next, the I.F. signal is filtered allowing the spread signal to pass while blocking other frequencies. A second mixer mixes the filtered I.F. signal with the second spread spectrum signal which is driven by the same spreading function as the first spread spectrum signal. The second spread spectrum signal is in step with the first spread spectrum signal such that only the desired signal is correctly de-spread from the I.F. signal while the spurious signals remain spread. The signal is then passed through a second filter which passes the desired narrow band signal while blocking much of the spurious spread signals. The amount of rejection provided by the second filter is a function of the ratio of the desired signal bandwidth to the spread spectrum bandwidth.

The significant features of the invention are illustrated in the Figures and described more fully below.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the prior art circuit for frequency translation of communication signals.

Figure 2 shows the preferred embodiment of the invention.

Figures 3A through 3F illustrate the frequency translation of signals using the invention.

Figure 4 shows a communications system using the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 2 shows the preferred embodiment of the invention. The invention is illustrated and described being used as a down-converter in a receiver. Those skilled in the art readily see that the invention is equally useful as an up-converter in a transmitter or in other frequency mixing applications. The frequency values illustrated are for descriptive purposes only and are not intended to limit the scope of the invention.

Down converter 20 is comprised of first mixer 21, first spread spectrum local oscillator(L.O.) 22, and filter 23. First mixer 21 mixes the radio frequency(R.F.) input signal with the spread spectrum local oscillator(L.O.) signal from first spread spectrum L.O. 22. First mixer 21 is any mixer commonly known in the art. In the illustrated embodiment, first mixer 21 mixes an 80 MHz R.F. input signal with a 90 MHz L.O. signal and outputs a 10 MHz spread spectrum intermediate frequency(I.F.).

First spread spectrum L.O. 22 is any spread spectrum L.O. commonly known in the art. The preferred embodiment uses a pseudo random frequency hopping type spreading function, however, any of several spreading functions may be used including chirp type spreading functions. The bandwidth of the first spread spectrum L.O. 22 is selected as a function of the desired rejection of the undesired spurious signals. The undesired spurious signals are rejected to a degree that is a function of the ratio of the bandwidth of the desired signal to the bandwidth of the spread spectrum L.O. signal.

First filter 23 is any signal filter commonly known in the art. First filter 23 passes the desired spread spectrum I.F. signal and blocks or rejects other undesired frequencies. First filter 23 is preferably wide enough to pass the bandwidth of the desired signal plus the spread spectrum signal from the first L.O. 22.

De-spreader circuit 25 is comprised of second mixer 26, second spread spectrum L.O. 27, and second filter 29. Second mixer 26 mixes the spread spectrum intermediate frequency(I.F.) signal from down converter 20 with the spread spectrum local oscillator(L.O.) signal from the second spread spectrum L.O. 27. Second mixer 26 is any mixer commonly known in the art used. In the illustrated embodiment, second

mixer 26 mixes a 10 MHz spread spectrum I.F. signal with a 9 MHz spread spectrum L.O. signal and outputs a 1 MHz de-spread signal.

Second spread spectrum L.O. 27 is similar to first spread spectrum L.O. 21, however, second spread spectrum L.O. 27 preferably operates at a lower frequency since it is primarily for de-spreading and not primarily for frequency translation. The second L.O. 27 is driven by the same spreading function as the first L.O. 21(i.e. the second L.O. is in step with the first L.O.) so that the desired signal is correctly de-spread from the spread spectrum I.F. signal. To achieve exact tracking, the preferred embodiment inserts delay 28 in the spreading signal path to delay the spreading function slightly to compensate for the delay introduced by first filter 23.

The output of second mixer 26 passes through second filter 29 which passes the desired narrow band signal while blocking other frequencies. Since the undesired spurious signals are still spread at the input to the second filter 29 and have a much wider bandwidth, second filter 29 easily attenuates them. The amount of rejection or attenuation provided by second filter 29 is determined by the ratio of the desired signal bandwidth to the spread spectrum bandwidth. Second filter 29 is preferably wide enough to pass only the narrow bandwidth desired signal.

Spreading function generator 24 is any spreading generator commonly known in the art. The preferred embodiment uses a frequency hopping type of spreading function, however, many other spreading functions such as chirp type spreading functions also work. The preferred embodiment also uses one spreading function generator to drive both L.O.'s 22 and 27. Those skilled in the art readily recognize that the single spreading function generator is easily replaced by two synchronized generators incorporated into each L.O.

In the described embodiment, only the I.F. signal resulting from the desired 80 MHz input signal will be spread correctly. Any I.F. signal resulting from the image input or other mixer spurious responses involving a harmonic of the first spread spectrum signal will be incorrectly spread at the wrong rate or in the wrong direction. In some systems, responses generated by harmonics of the first spread spectrum signal are actually the desired signals. By using appropriate de-spreading functions known to those skilled in the art, any one of the responses can be correctly de-spread as the desired output and the others rejected.

Those skilled in the art readily recognize alternate yet equivalent embodiments of this invention. Many different frequencies and spreading functions are equally suitable for proper operation of the invention. Alternate embodiments envision independent synchronized spreading functions built into each L.O., additional filters, and alternate delay circuit locations.

Figures 3A through 3F illustrate the frequency translation of signals using the invention and how undesired signals are attenuated by the invention. The graphs show frequency along the X axis and signal strength along the Y axis.

Figure 3A shows two possible R.F. input signals which feed first mixer 21 in Figure 2. A desired signal 30 is shown centered at 80 MHz and an undesired signal 31 is shown centered at 100 MHz. Depending on the bandwidth of the signals and other factors, it may be difficult using the prior art to built filters to block the undesired signal 31. Figure 3B shows the spread spectrum L.O. signal generated by the first L.O. 22 in Figure 2. First spread spectrum L.O. signal 32 is centered at 90 MHz. The arrow through the mid portion of first L.O. signal 32 indicates the signal is spread spectrum and moving as indicated.

Figure 3C shows the spread spectrum I.F. signal output of first mixer 21 in Figure 2. Since 90 MHz - 80 MHz = 10 MHz, and since 100 MHz - 90 MHz = 10 MHz, both the desired signal 30 and the undesired signal 31 are mapped to the same frequency. In other words, the desired signal is correctly spread in the bandwidth but the undesired signal in not. This is indicated by arrows 34 and 35. Arrow 34 indicates the desired signal is moving in step with the first L.O. signal while arrow 35 illustrates the undesired signal moving in the opposite direction. Those skilled in the art understand that even though both signals are spread across the same frequency range, the desired signal may be recovered since it is spread differently from the undesired signal.

The spread spectrum signals shown in Figure 3C feed into second mixer 26 in Figure 2 where they are mixed with second spread spectrum L.O. signal 36 shown in Figure 3E centered at 9 MHz. Figure 3D is identical to Figure 3C but is rescaled to aid understanding of Figures 3E and 3F. Second L.O. signal 36 represents the output of second spread spectrum L.O. 27 in Figure 2. Second L.O. signal 36 is driven by the

same spreading function as the first L.O. 32 and therefore correctly de-spreads the desired signal 30 from spread spectrum I.F. signal.

Figure 3F illustrates the output of second mixer 26. Since 10 MHz - 9 MHz = 1 MHz, both the desired signal and undesired signal are translated to 1 MHz. However, the undesired signal remains spread, as indicated by arrow 37, while the desired signal has been correctly de-spread to normal bandwidth. The signals of Figure 3F are input to second filter 29 where the undesired signal is rejected as a function of the ratio of desired signal bandwidth to spread spectrum bandwidth.

The invention is particularly useful in communications systems which process weak signals such as those used in satellite communications. Figure 4 illustrates a satellite communications system using the invention in both the transmitter and the receiver. Ground station 40 uses the invention in a transmitter to generate signal 41. Signal 41 is transmitted to satellite 42 where it is either reflected or re-transmitted. When satellite 42 is a repeater type satellite, it uses the invention to in both its receive and its transmitter. Signal 41 is received by a receiving station such as aircraft 43 which uses the invention in a receiver to receive signal 41 and reject spurious signals.

The invention can be used alone or as an adjunct to conventional spurious rejection techniques to achieve improved performance. The use of digital signal processing techniques, although not required to practice the invention, can ease implementation of the invention. This is particularly true if direct digital synthesis techniques are used to generate the spread spectrum L.O.'s. The I.F. signal is then digitized and the de-spreading function performed using digital signal processing techniques.

This detailed description of the invention is intended for descriptive purposes only and is not intended to limit the scope of the invention. Although this description has described the invention as used in a communications system, those skilled in the art readily recognize that the invention is useful in many other applications. This includes, but is not limited to, multipliers used in sample and hold systems for analog to digital converters, digital communications, digital radios, and generally any device that uses multipliers.

It is clear from the foregoing that the present invention represents a new and useful circuit for mixing signals and rejecting spurious signals.

CLAIMS

The embodiments of an invention in which an exclusive property or right is claimed are defined as follows:

1. A spurious response rejecting mixer apparatus for frequency translating a desired input signal and rejecting spurious signals in a communications system, said apparatus comprising:

a) a first mixer having a first input, a second input, and an output, said first input for receiving said desired input signal;

b) a first local oscillator, said first local oscillator generating a first spread spectrum signal, said first local oscillator in communication with said second input of said first mixer;

c) a second mixer having a first input, a second input, and an output, said first input in communication with said output of said first mixer; and,

d) a second local oscillator, said second local oscillator generating a second spread spectrum signal driven with the same spreading function as said first local oscillator such that said second mixer correctly de-spreads said desired input signal.

2. The spurious response rejecting mixer apparatus according to claim 1 further comprising a first filter interposed between said output of said first mixer and said first input of said second mixer, said first filter passing frequencies containing said desired input signal and rejecting signals in other frequencies.

3. The spurious response rejecting mixer apparatus according to claim 2 further comprising a second filter in communication with said output of said second mixer, said second filter passing frequencies containing said desired input signal and rejecting signal in other frequencies.

4. The spurious response rejecting mixer apparatus according to claim 3 further comprising a spreading function generator in communication with said first mixer and said second mixer, said spreading function generator communicating a spreading function to said first mixer and said second mixer.

5. The spurious response rejecting mixer apparatus according to claim 4 further comprising a delay circuit interposed between said spreading function generator and said second input of said second mixer.

6. A mixing circuit for mixing an input signal with local oscillator signals and rejecting spurious responses, said mixing circuit comprising:

a) first spread spectrum oscillation means for generating a first spread spectrum signal;

b) first mixing means for mixing said input signal and said first spread spectrum signal and for generating a spread spectrum intermediate signal;

c) second spread spectrum oscillation means for generating a second spread spectrum signal which is in step with said first spread spectrum signal; and,

d) second mixing means in communication with said first mixing means for mixing said spread spectrum intermediate signal and said second spread spectrum signal and for generating an output signal containing a de-spread desired signal.

7. The mixing circuit according to claim 6 further comprising first filter means for filtering said spread spectrum intermediate signal such that desired predetermined signal frequencies are passed and undesired frequencies are blocked.

8. The mixing circuit according to claim 7 further comprising second filter means for filtering said output signal such that desired signal frequencies are passed and undesired frequencies are blocked.

9. The mixing circuit according to claim 8 further comprising delay means in communication with said second mixing means for delaying said second spread spectrum signal.

10. The mixing circuit according to claim 9 further comprising spreading function means for communicating a spreading function to said first spread spectrum oscillation means and said second spread spectrum oscillation means.

11. A communications system comprising:

a) transmitter means for transmitting a communication signal, said transmitter means comprising,

1) a first spread spectrum oscillator generating a first spread spectrum signal;

2) a first mixer having a first input for receiving said communication signal, a second input in communication with said first spread spectrum oscillator for receiving said first spread spectrum signal, and an output;

3) a second spread spectrum oscillator generating a second spread spectrum signal being in step with said first spread spectrum signal; and,

4) a second mixer having a first input in communication with said output of said first mixer, a second input in communication with said second spread spectrum oscillator, and an output; and,

b) a receiver for receiving said communication signal.

12. The communications system according to claim 11 wherein said transmitter means includes a first filter interposed between said output of said first mixer and said first input of said second mixer, said first filter passing desired signal frequencies and blocking undesired signal frequencies.

13. The communications system according to claim 12 wherein said transmitter means includes a second filter in communication with said output of said second mixer, said second filter passing desired frequencies and blocking other frequencies.

14. The communications system according to claim 13 wherein said transmitter means includes a delay circuit in communication with said second spread spectrum oscillator, said delay circuit delaying said second spread spectrum signal by a predetermined amount of time.

15. A communications system comprising:

a) a transmitter for transmitting a communication signal; and,

b) a receiver for receiving said communication signal, said receiver comprising,

1) first spread spectrum oscillation means for generating a first spread spectrum signal;

2) first mixing means for mixing said communication signal and said first spread spectrum signal and generating a spread spectrum intermediate frequency signal;

3) second spread spectrum oscillation means for generating a second spread spectrum signal which is in step with said first spread spectrum signal, and,

4) second mixing means for mixing said spread spectrum intermediate frequency signal and said second spread spectrum signal and generating an output signal.

16. The communications system according to claim 15 wherein said receiver includes a first filter means interposed between said first mixing means and said second mixing means for filtering said spread spectrum intermediate frequency signal such that desired signal frequencies are substantially passed and other frequencies are substantially blocked.

17. The communications system according to claim 16 wherein said receiver includes second filter means in communication with said second mixing means for substantially passing desired signal frequencies and substantially blocking other frequencies.

18. The communications system according to claim 17 wherein said receiver includes a delay circuit in communication with said second spread spectrum oscillation means, said delay circuit delaying said second spread spectrum signal by a predetermined amount of time.

19. A method of mixing a desired signal with local oscillators for frequency translating the desired signal and rejecting spurious signals, said method comprising the steps of:

a) providing a first mixer and a second mixer;

b) providing a first local oscillator for generating a first spread spectrum signal and a second local oscillator for generating a second spread spectrum signal, said second spread spectrum signal in step with said first spread spectrum signal;

c) mixing said desired signal and said first spread spectrum signal in said first mixer and generating a spread spectrum intermediate signal;

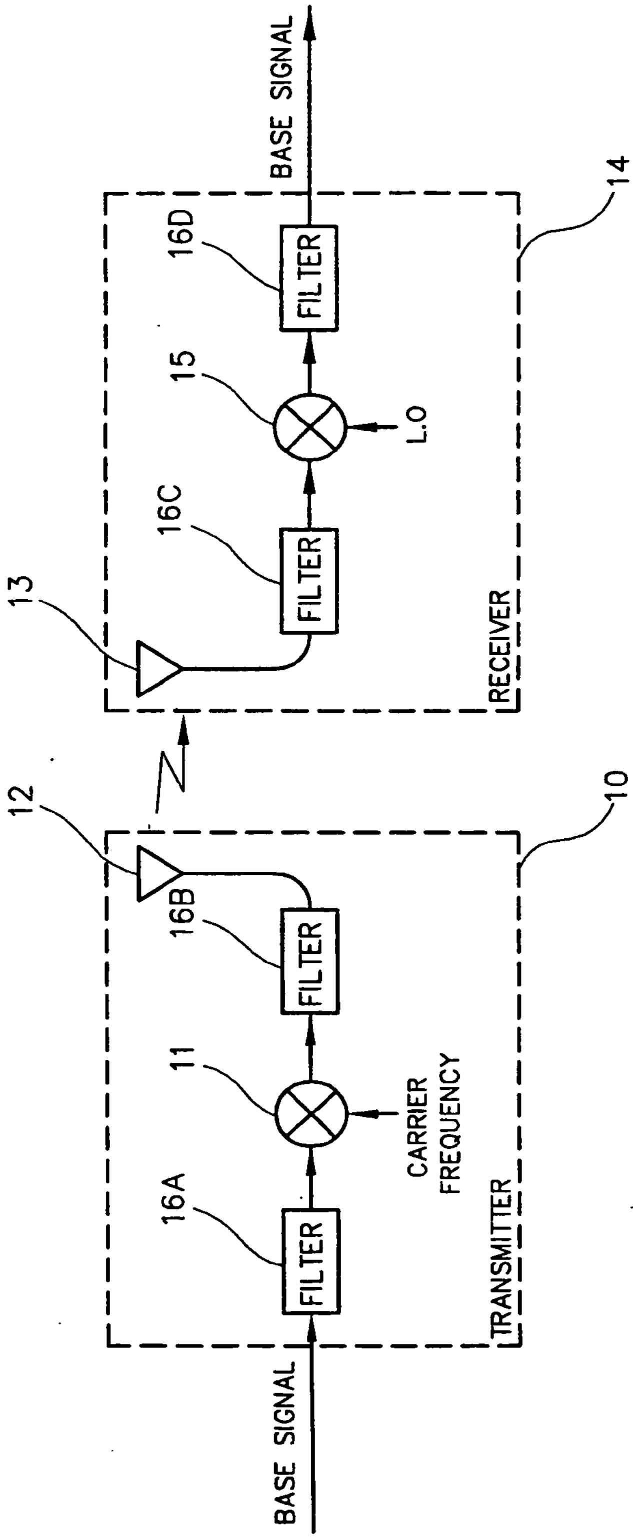
d) mixing said spread spectrum intermediate signal and said second spread spectrum signal in said second mixer and generating an output signal.

20. The method according to claim 19 wherein the step of mixing the desired signal is followed by the steps of:

a) providing a first filter suitable for passing frequencies containing said desired signal in said spread spectrum intermediate signal; and,

b) filtering said spread spectrum intermediate signal with said first filter.

21. The method according to claim 20 wherein said second local oscillator includes a delay circuit providing a delay equal to the delay induced to said intermediate signal by said first filter.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11
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16C
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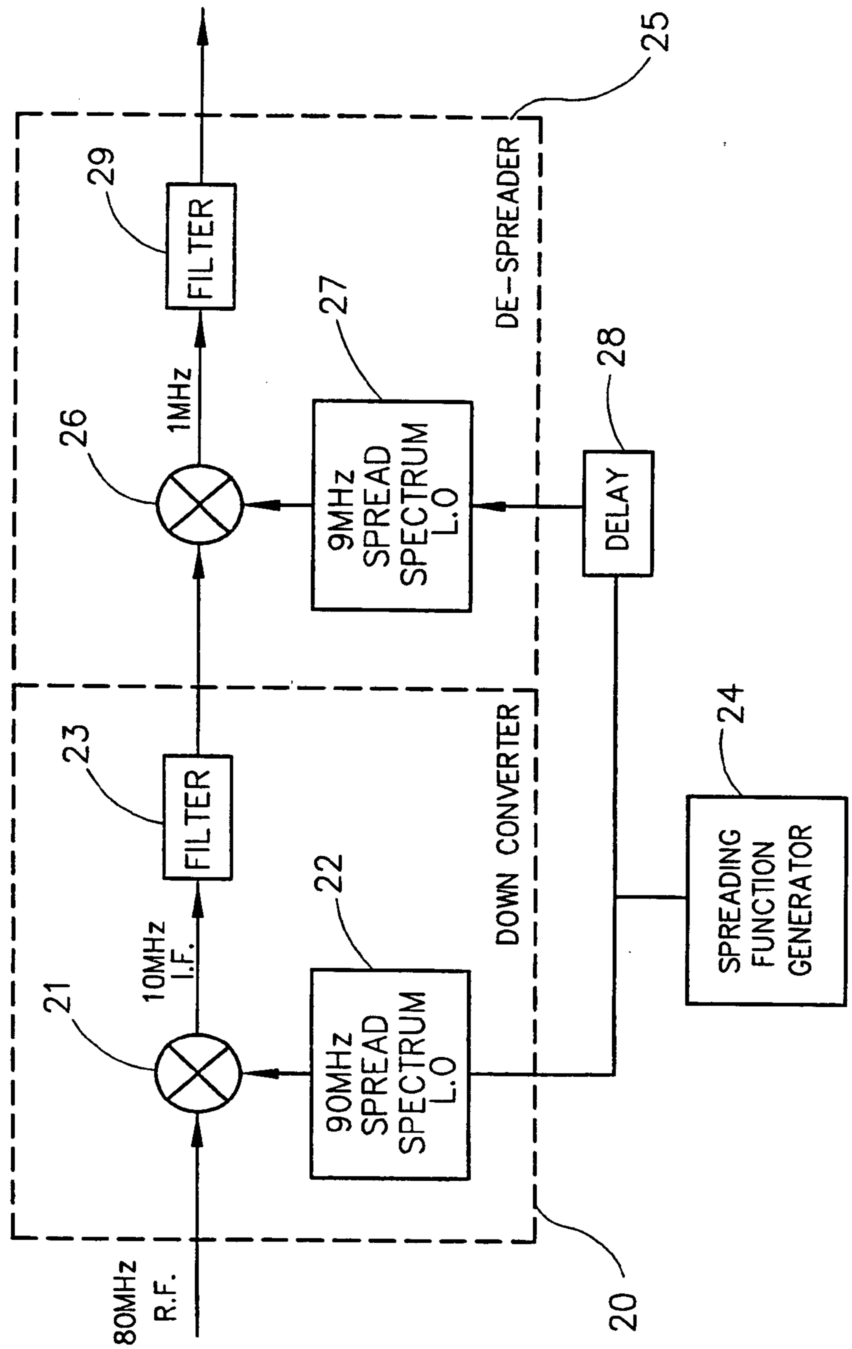
L.O
FILTER
16D
RECEIVER
14
BASE SIGNAL

Fig. 1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10MHz
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90MHz
SPREAD
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L.O
9MHz
SPREAD
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L.O
DOWN CONVERTER
DE-SPREADER
DELAY
SPREADING
FUNCTION
GENERATOR
20
21
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Fig.2

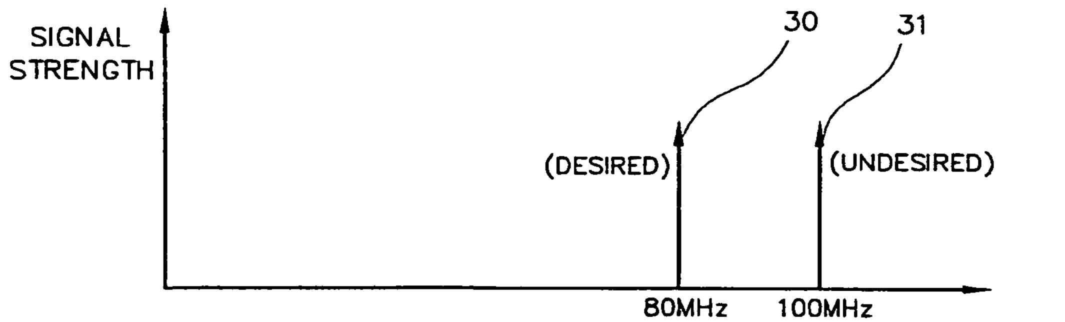

Fig. 3A

Fig. 3B

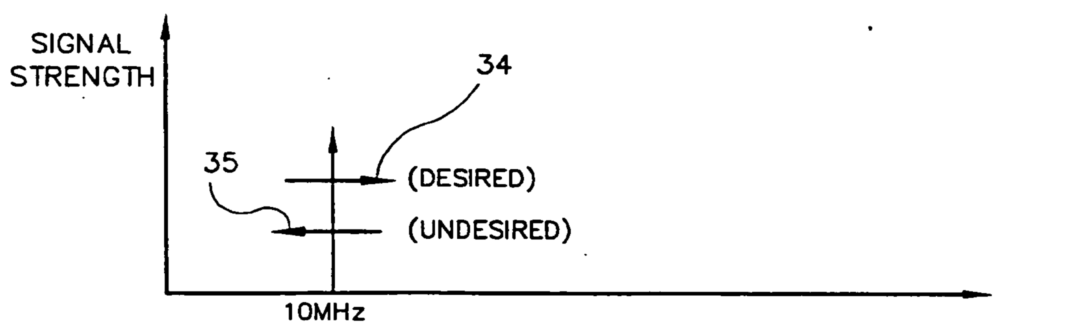

Fig. 3C

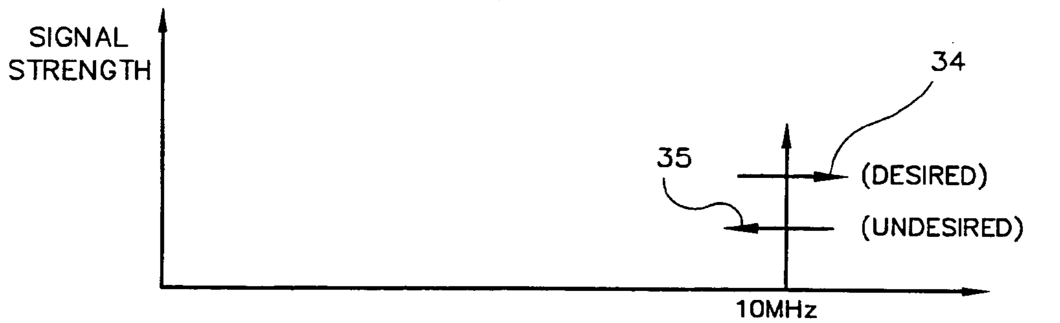

Fig. 3D

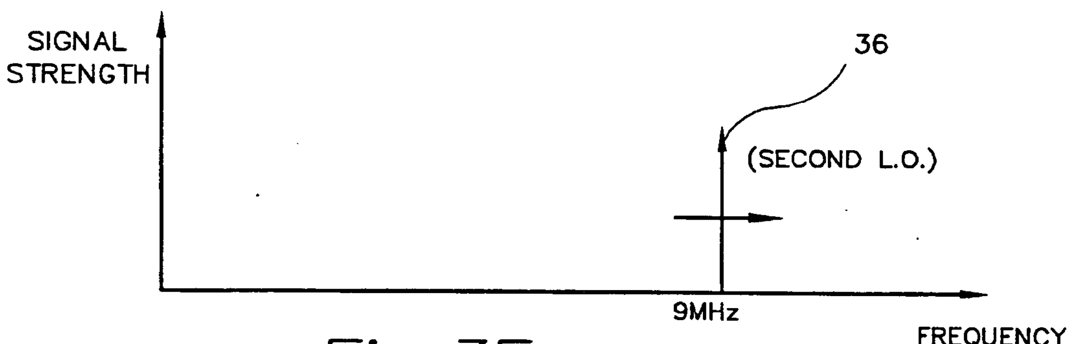

Fig. 3E

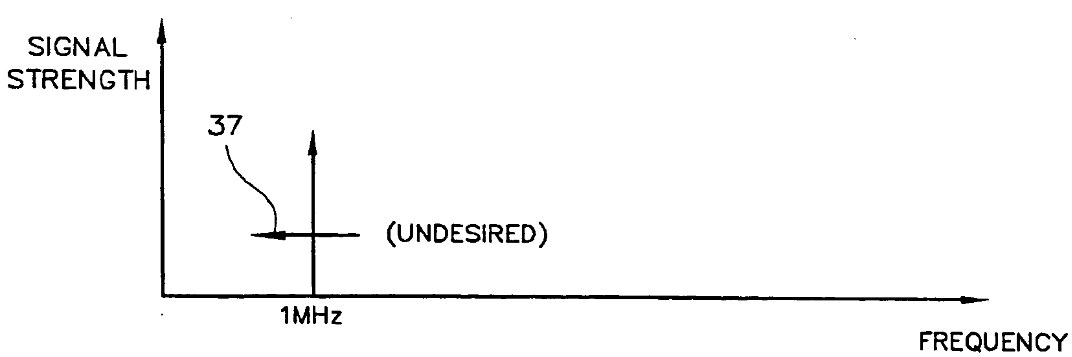

Fig. 3F

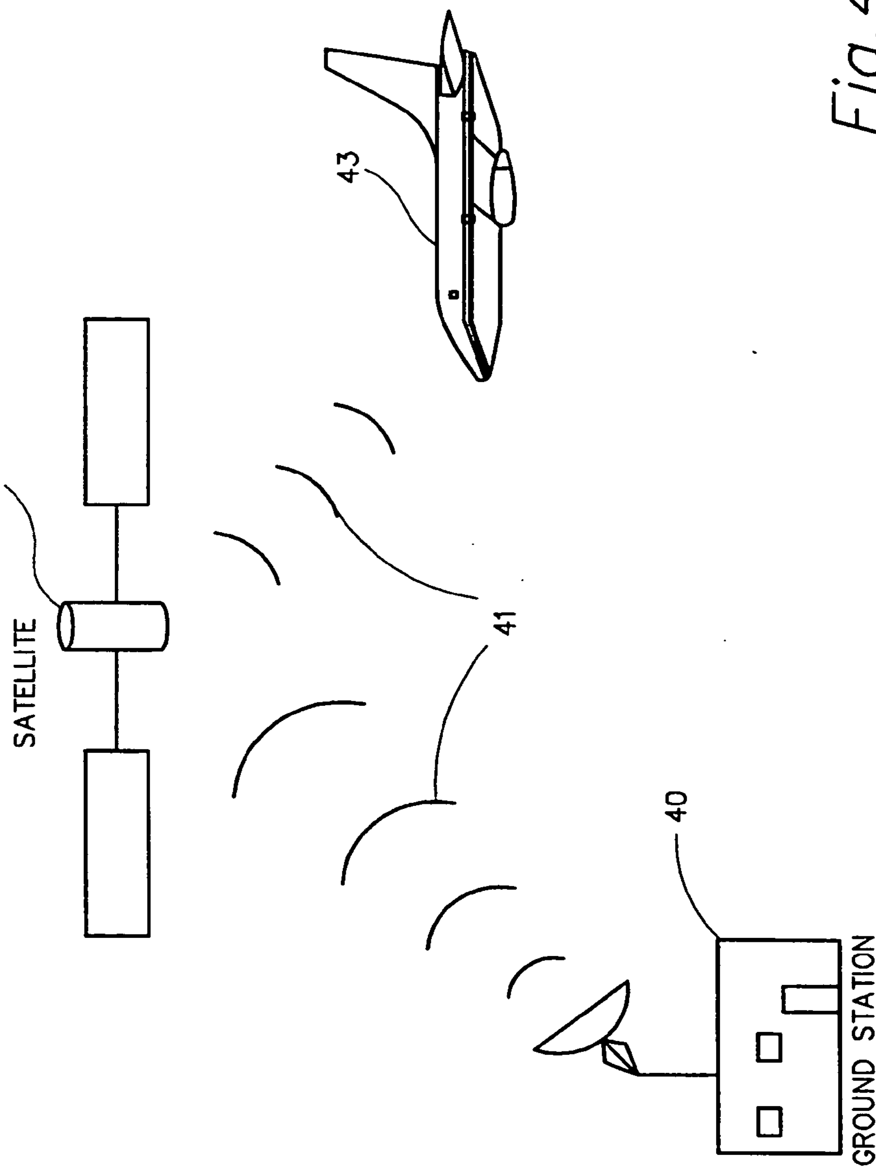

Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/08019

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H03D7/16 H04B1/707 H04B1/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H03D H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 6 no. 103 (E-112) ,12 June 1982 & JP,A,57 035427 (MITSUBISHI) 26 February 1982, see abstract ---	1-4,6-8, 11-13, 15-17, 19,20
A	EP,A,0 435 593 (XEROX) 3 July 1991 see abstract; figure 1 ---	1,6,11, 15,19
A	GB,A,2 228 378 (TELENOKIA) 22 August 1990 see abstract; figures 1,2 -----	1,6,11, 15,19

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☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 October 1995	13.10.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Andersen, J.G.

INTERNATIONAL SEARCH REPORT

Inform[redacted] patent family members

Inte [redacted] Application No
PCT/[redacted] 95/08019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-435593	03-07-91	JP-A- 4101526	03-04-92
		US-A- 5222075	22-06-93
GB-A-2228378	22-08-90	AU-B- 4792490	19-07-90

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